DIRECTED STUDENT ENGAGEMENT AND LEARNING IN A LARGE ENGINEERING UNIT.

D J Hargreaves

Science and Engineering Faculty, Queensland University of Technology, Australia

ABSTRACT

Most students when entering tertiary education have little idea what an engineer actually does. It is critical, therefore, that students transitioning into their university engineering program are exposed to learning experiences that allow them to grasp very early in their studies an understanding and appreciation of what real engineering practice is, and how this practice fits with their chosen degree program and how it supports their career aspirations. In 2011, the author was driven by an abiding commitment to broaden students' understanding of this profession, their insight into the scope of their capabilities as professional engineers, and to inspire and motivate them through learning about the challenges and opportunities they will face as professionals. It was from this premise that he spearheaded the development and introduction of a new core first year unit, a unit focused on real engineering practice. As a 'transition in' unit for predominantly domestic and secondary school leaver student cohorts, the unit served as a gateway to all engineering disciplines. The author's positive impact and influence on student learning was based on CDIO methodology through 'directed' peer- and self-learning leading and teaching this unit in collaborative learning spaces and integrating the *Engineers Without Borders Challenge* into it. Despite the size of this 1000+ student cohort and teaching team of 20+ tutors, student satisfaction scores (as judged by QUT evaluation indictors) jumped in the first year of implementing this teaching approach to 4.5 (on a 5-point scale); this satisfaction remains high with students' evaluation scores averaging 4.4, exceeding both the faculty (4.0) and university (4.1) averages over this same period. This innovative approach also halved the attrition rate for first year engineering.

KEYWORDS

Student engagement, Student learning, Directed self-learning, Directed peer-learning, Professional skills
Standards: 1, 2, 3, 4, 5, 6, 8, 10, 12.

CONCEPT

Most students when entering tertiary education have little idea what an engineer actually does. It is critical, therefore, that students transitioning into their university engineering program are exposed to learning experiences that allow them to grasp very early in their studies an understanding and appreciation of what real engineering practice is, and how this practice fits with their chosen degree program and how it supports their career aspirations. In 2011, the author was driven by an abiding commitment to broaden students' understanding of this profession, their insight into the scope of their capabilities as professional engineers, and to inspire and motivate them through learning about the challenges and opportunities they will face as professionals. It was from this premise that he spearheaded the development and introduction of a new core first year unit, a unit focused on real engineering practice. As a 'transition in' unit for predominantly domestic and secondary school leaver student cohorts, the unit served as a gateway to all engineering disciplines.

The author's own extensive experience in teaching showed that most students 'don't learn anything in lectures'. He has published many papers that describe various initiatives that were undertaken as incremental steps in addressing this observation, for example Hargreaves (1998, 2001).

The primary aims therefore of this initiative were

- to change the way that teaching is conducted from teacher-centred to an active student-centred approach,
- to utilise a completely different learning space, and
- to broaden the student understanding of what real engineering is and in particular to emphasise the particular skills and capabilities that a graduate engineer needs as he/she enters the workforce.

DESIGN

Student Learning

The lecture theatre with tiered seating and focus on strong lecture style didactic delivery is viewed by many undergraduates as the "typical" class however, they do not feel they get a lot out of them according to Boles et al (2010). Felder and Brent (2005) explored differences in learning styles and the methods traditionally used in engineering courses. The lecture style as "one-size-fit-all", they observe, fits almost nobody. Low attendance rates at lectures also indicate the current student view of this mode of delivery. The role of the lecturer was predicted to change from the traditional 'sage on the stage' to that of a facilitator (Hargreaves and Ternel (1997)). Almost two decades later, this perspective has not changed: it parallels current teaching approaches and strongly resonates with a long-held belief that peer learning and teamwork are crucial in developing the global engineer, a view also shared by industry. It was from this basis that the author guided ('directed') his students' learning, inspiring and motivating them to embark on a self-learning journey about what it means to be a professional engineer.

Learning Spaces Design

New spaces designed to facilitate active and collaborative learning supported by technology are known by many names. They are all moving toward the mix of furniture, layout and technology that support active and collaborative learning. In this paper, the author refers to the space generically as Collaborative Learning Space (CLS).

The design of what is sometimes also referred to as 21st Century or Next Generation Learning Spaces is very well documented, for example Joint Information Systems Committee (2006), Oblinger (2006) and Rasmussen et al (2012). "Many of today's learners favour active, participatory, experiential learning" and that "their behaviour may not match their self-expressed learning preferences when sitting in a large lecture hall with chairs bolted to the floor", Oblinger (2006). "Spaces are themselves agents for change. Changed spaces will change practice" (Joint Information Systems Committee, 2006).

A plan and typical fit out for CLS used in this unit at QUT are shown in Figure 1.

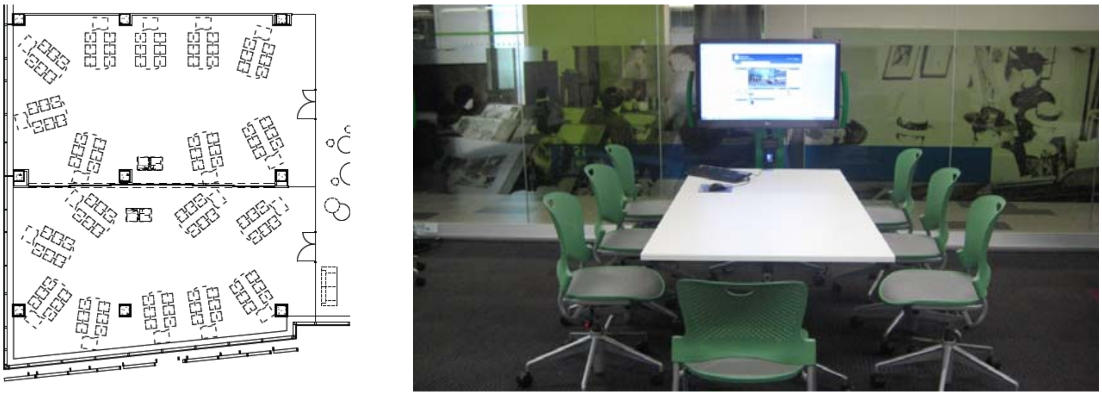

Figure 1: Collaborative Learning Space plan and fit out

Radcliffe et all (2008) developed a spectrum for places of learning; from completely structured such as the tiered lecture theatre to very unstructured such as at home or in a public place – see Figure 2. The CLS proposed here is indicated towards the structured end of the spectrum; the reason for this to be made more clear as a description of the actual processes of learning are described in more detail.

c

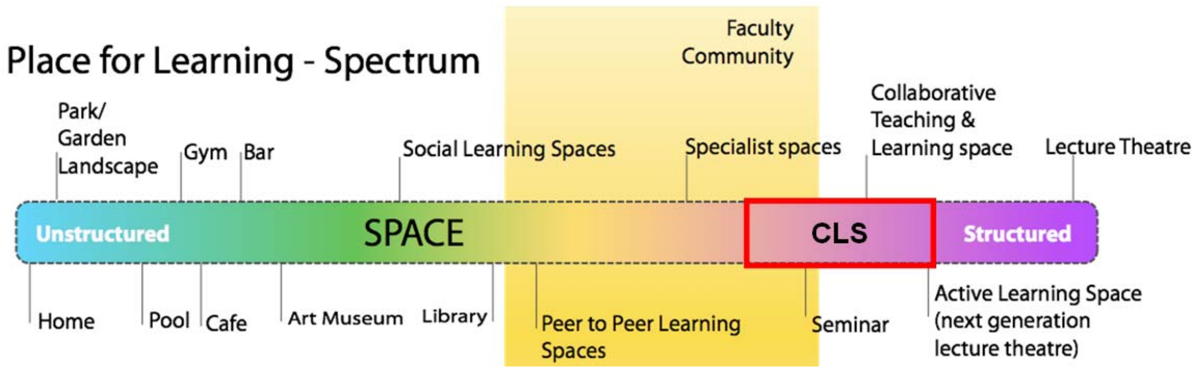

Figure 2: Place for Learning – Spectrum
Adapted from (Radcliffe et al., 2008)

Graduate capabilities

The Engineers Without Borders (EWB) Challenge was used as the spine that essentially integrated all of the particular skills and capabilities that were to be covered in this initiative. This is a humanitarian project that requires groups of first-year students to solve some problem or problems that exist usually in an overseas country. Employers of graduate engineers frequently indicate that their technical skills are more than satisfactory but professional skills are lacking. Professional skills include oral and written communication, ability to work effectively in teams, have an appreciation of ethical considerations and cultural differences (and this is becoming very important as engineering becomes a very global profession), being able to solve a problem such that sustainability is a main criterion in the design, being able to manage projects effectively, to be able to conduct research, as well as critically analyse existing information and/or projects especially when projects are very complex and contain many aspects.

Each of these professional skills were addressed and strongly aligned with the EWB project.

IMPLEMENT

There were about 1000 students undertaking this unit of study. Each of the Collaborative Learning Spaces (CLS) could accommodate up to about 50 students. The CLS was arranged such that six students sat around a table with full access to the internet and each with a large screen. There were up to eight such tables in any particular CLS. The lecturer/tutor/facilitator has control of each screen and is able to move images from one screen to all others and/or show it on the main screen. This arrangement meant that students were quickly introduced to at least a few other students. This is a crucial element as it is well-known that many students leave university because they feel isolated as they enter large cohorts compared to their secondary school days. They were allocated into groups in their very first tutorial. Obviously there needs to be about 25 different 'tutorials' each week. Students were required to attend one tutorial each week, each tutorial being two hours in length.

Unit Framework

Formal lectures were timetabled and in Week 1, the one hour lecture focused on 'What is engineering' and outlined how the unit would be run throughout the semester including the rationale for the unit being in the course, the learning outcomes for the unit, the importance of considering sustainability in every engineering design and the assessment of each learning outcome. In subsequent weeks, invited/guest lecturers from industry would present on particular aspects of engineering for example 'My first three years as a graduate civil engineer', 'How BMW are responding to customer requirements of sustainable modes of transport', and 'The importance of considering renewable sources of energy in all engineering product, process and system design'. Some of these lectures were more for general interest rather than be directly related to the assessed learning outcomes but there was always a strong message about what potential careers exist for graduates.

It was strongly recommended that students attend all tutorials. These are working tutorials and students worked in teams on given activities for much of the two-hour session. These tutorials always included short 'lectures' of about 10 minutes to introduce a new topic followed by directed activities, for example, as a team, find some examples of good oral communications. There may be several of these short lectures and activities in any one tutorial. Students engaged with the short lecture and then enthusiastically used the internet to complete the allocated task. When each task was completed, at least one member from each team was required to stand up and tell the rest of the teams what his/her team had found. This process is clearly dependent on the tutor 'directing' the students to complete a job but the job is done is a team environment and so both directed self- and peer-learning occurs.

The Unit coordinator prepared all material to be covered in the tutorial sessions and made it available to all tutors prior to the first tutorial each week.

Engineers Without Borders (EWB) prepare a challenge for all first year engineering students across Australia every year. It is an humanitarian project based usually in a developing world country. There are at least seven areas (and often subsets of these areas) from which the team can select; this ensures that all disciplines of engineering are covered. This project is the ‘spine’ that holds the whole unit together, that is all professional skills development are intricately connected to this project.

Choice of tutor and tutor training.

From the description of the Unit Framework above, it is clear that this is not conventional lecture and tutorial practice. The choice of tutor is therefore vital to the success of this new method of student learning. Tutors needed to be flexible in their approaches, be confident in their ability to respond to students’ questions and have sufficient experience in the real world so that they can bring real examples to the tutorial sessions. The Unit coordinator met with tutors before the semester began and explained in some detail how this unit would run and met with them on a regular basis in order to address any issues that arose and to assist some tutors in content/material, especially examples. Tutors were encouraged to find their own examples of where this particular piece of content is used by practicing engineers. Most of the tutors were either postgraduate students or third and fourth year engineering students or technical support staff in engineering.

Graduate Capabilities.

Teamwork

Team members were first required to share contact details and share something about themselves including strengths and capabilities in terms of the EWB project that they would undertake throughout the semester. Each team develops their ‘rules of behaviour’ as well as the consequences of not obeying the team rules. This is done very early in the semester. Each team must write the minutes of each team meeting and make them available to their tutor. The minutes must include attendance, tasks completed and tasks allocated with timeframes. These requirements are generally not appreciated by the students at the beginning of the semester but certainly are towards the end of the semester. It is usually towards the end of the semester that ‘things go wrong’ in teamwork; for example one member not contributing to the project. Each tutor discusses with each team every week any issues or concerns and progress being made on the project.

‘*Teamwork is critical to success in all of these learning endeavours, and while initially that may seem like a harsh constraint to place on students, it certainly fully reflects the nature of graduate work in the engineering field*’ [Student, Unit Reflection, 2014].

Oral communication

As indicated above, each team member will have made several short presentations to the class throughout the semester. None of these are assessed. Students, especially those who do not feel confident in speaking in public really appreciate the opportunity to speak in a safe and non-assessed environment. At the end of the semester, each team must make a formal presentation to the rest of the class and in most cases, invited guests from industry are also present. This is a team presentation on their EWB project, so the team needs to arrange which member speaks about what part of the project whilst staying within the required time limit. Observations from all tutors are that there is a very significant improvement in oral communication from the beginning to the end of the semester. Throughout all tutorials, team and class discussions assisted in the development of this capability.

'*Through our weekly tutorials, we have been given numerous opportunities to speak in front of the class about real world situations raised during the lesson. These continual in-class speeches have helped me greatly in broadening my public speaking skills*' [Student, Unit Reflection, 2013]

'*After several years of teaching into this year, I have seen a dramatic improvement in the performance of student groups particularly around their ability to present'* [ENB100 Tutor comment, 2015]

Written communication

Students are required to perform a small research project each week and write a small report on it [no more than one page]. An example is "find four different definitions of sustainability, write your own definition and why is sustainable development so important in all engineering projects". These are marked on an individual basis and returned to the students every week. Referencing is very important in all of these small projects. Students generally did not like this process during the semester but did appreciate the significance and importance at the end of the semester when their full EWB report was being prepared. The EWB report was assessed as a team result.

'*The weekly progress reports provided the opportunity to enhance our research skills on specified topics; these helped with my writing skills especially correct referencing*' [Student, Unit Reflection, 2013].

'*The progress reports … proved to be extremely valuable in my understanding of what it takes to be a true and competent engineer*' [Student, Unit Reflection, 2014].

Cultural diversity

Following team and class discussions on what is culture and examples of cultural differences, teams were asked to find images of typical houses in various countries around the world, for example Iceland and Australia. The team was then asked to discuss possible differences in culture based on these images. Then they were asked to consider how cultural diversity could affect the designs or processes in their EWB project. Obviously, the message was to ensure that their design fitted the local culture. There are about 15% international students in these tutorials so the tutor is able to use the experience of these students to emphasise the importance of cultural diversity.

Ethical considerations.

This topic was approached in a similar manner to that on cultural diversity. Students need to understand that ethical considerations in one country may vary quite markedly to those in Australia. In their teams, students were asked to find examples of ethical and non-ethical practice in engineering. The discussion around this task was generally quite noisy and many students had very definite views on ethics. Again, using the experience of international students assisted in cementing the appreciation and importance of ethical considerations on any engineering design.

Research

The comments on written communication above indicate the need for students to research various topics on a weekly basis.

Project management

In teams, students were first asked to break a larger task into smaller one and then write them on a separate piece of paper. The next step was to arrange the smaller tasks into chronological order to that the larger task could be completed. Then the team was required to modify the structure of their pieces of paper considering that three persons were available to do the larger task. What each team developed was a Gantt chart. An example of such a task was to change a tyre on a car at night. Teams were then asked to develop a Gantt chart for their EWB project.

Sustainability.

As previously indicated, sustainable development was a prime part of this unit. Students firstly gained some appreciation of how engineering projects can be more sustainable than others. Students were directed to find why the Japanese bullet train is so shaped; why aeroplane wings have special designs on their wingtips, how Velcro was developed and several other such designs that we take for granted. This is clearly about biomimicry. Another activity related to their EWB project was about materials of construction. Can you use bamboo as a building material in certain parts of south-east Asia? Yes it is has very good building characteristics but if you use too much, you will destroy the habitat for chimpanzies. So now integrate ethical considerations with choice of building material. The prime message with this very important consideration, sustainable development, is to ensure that the design is sustainable and may involve several other considerations such as how to transport the building material to the building site.

Assessment of graduate capabilities.

Not all graduate capabilities were individually or specifically assessed. Total assessment was about 40% individual and about 60% based on teamwork.

OPERATE

The author guided (‘directed’) his students’ learning, inspiring and motivating them to embark on a self-learning journey about what it means to be a professional engineer. With this particular student demographic, combined with the author’s extensive teaching and industrial experience, these first year students are not yet ready to ‘go it alone’. As such, they are not expected to be self-directed learners; instead, tutors ‘direct’ them to what they should learn. This is facilitated in technology-rich, collaborative learning spaces through the formation of small study groups who remain working together throughout the entire semester. By flipping the concept of self-directed learning to ‘directed’ peer- and self-learning, the students are motivated and supported by their peers during their first year learning journey at university.

Despite the size of this 1000+ student cohort and teaching team of 20+ tutors, student satisfaction scores (as judged by QUT evaluation indictors) jumped in the first year of implementing this teaching approach to 4.5 and above (on a 5-point scale); this satisfaction remains high with students’ evaluation scores averaging 4.4, exceeding both the faculty (4.0) and university (4.1) averages over this same period. This innovative approach also halved the attrition rate for first year engineering.

Students really appreciated the visiting/guest lectures as they brought real world engineering examples to the classroom and/or extended students' appreciation of for example the utilization of renewable energies.

'*Their presentations were great examples of how engineers should present to others and communicate. These [guest] lectures reinforced the principles presented in lectorials*' [Student, Unit Reflection, 2012].

Formal feedback from students indicated very clearly that this approach to teaching and learning through much improved student engagement was preferable to the formal 'sage on the stage'.

An unforeseen consequence of introducing this approach was that the attrition [students leaving engineering] halved to about nine percent. For the first time in many cases, students received a real world appreciation of what real engineers do in their daily work. This reinforced their choice of engineering for a career or did not. In both scenarios, it is a good outcome. This is because that the word 'engineering' is rarely used in primary and secondary education.

The EWB Challenge underscored not only the types of engineering designs/processes that engineers encounter in the real world but more importantly demonstrated that engineers need to possess a wide range of professional skills and capabilities and can make significant positive differences to the sustainable development in this world.

'*The EWB challenge … gives a real world application to engineering, and shows how engineers can help impoverished nations. It also gives real world application to sustainability in the world and why it is so important*' [Student, Unit Evaluation, 2013].

CONCLUSIONS

Using the CDIO framework to design and deliver this new unit has been very successful. The move from lecture-centred to student-centred learning has been greatly appreciated by most students.

Utilisation of the Collaborative Learning Spaces has been such a success at QUT that the university is modifying and refurbishing existing rooms so that this mode of student engagement and learning is the norm rather than the exception across the university.

The particular implementation of a combination of directed self- and peer-learning has also been shown by student comment and student evaluation of teaching to be a very acceptable mode of learning. Tutors 'directed' students towards particular topics and discussion in individual teams and across teams assisted all students in not just their learning but also in the development of their professional skills.

REFERENCES

Boles, W., Jolly, L., Hadgraft, R., Howard. P., & Beck, H. (2010). Influences on student learning in engineering: Some results from case study fieldwork. *Australasian Journal of Engineering Education*, *16*(2), 149-165

Felder, R. & Brent, R. (2005), Understanding student differences, *Journal of Engineering Education*, 94(1), 57-72

Hargreaves, DJ (1998): Promoting understanding through active participation in tutorials and lectures, *10th AaeE Conference, Gladstone, Sept. pp 75-79*.

Hargreaves, D. J., & Ternel, I. D. (1997). The changing role of the engineering educator*. 9th AaeE Conference, Ballarat, Vic*

Hargreaves DJ (2001): Integrating workplace experience into an engineering curriculum", *Proc "Effective Teaching and Learning" conference, Brisbane, 12-14 November*

Joint Information Systems Committee. (2006). Designing Space for Effective Learning: A Guide to 21st Century Learning Space Design. Retrieved August 12, 2012, from www.jisc.ac.uk

Oblinger, D. G., ed., (2006). Learning Spaces. Retrieved from www.educause.edu/learningspaces

Radcliffe, D., Wilson, H., Powell, D. & Tibbetts, B. (2008) Designing Next Generation Places of Learning: Collaboration at the Pedagogy-Space-Technology Nexus. Retrieved August 12, 2012, from www.uq.edu.au/nextgenerationlearningspace/

Rasmussen, R., Dawes, L., Hargreaves, D., & James, J. (2012). From tiers to tables—enhancing student experience through collaborative learning space. *Proceedings of the 2012 AaeE Conference,* Melbourne, Vic.

BIOGRAPHICAL INFORMATION

Doug Hargreaves AM has published over 50 refereed papers in the field of engineering education during his 28 year academic career. In 2011, he returned to teaching following seven years as Head of School of Engineering Systems with 135 staff. He was driven by a desire to ensure students entering engineering had an understanding of the profession. He has published over 100 refereed papers in his discipline of tribology as well as about 10 papers on leadership including one book, "Values-Driven Leadership". In 2010, he was the National President of Engineers Australia with about 100 000 members. He was awarded a Member of the Order of Australia in June 2014 for his significant contribution to engineering education, the profession and the community.

Corresponding author

Prof Doug Hargreaves AM
Queensland University of Technology
2 George Street
Brisbane, Australia 4001
+61 417 163 629
d.hargreaves@qut.edu.au